Hospital Variation in the Use of Noninvasive Cardiac Imaging and Its Association With Downstream Testing, Interventions, and Outcomes

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IMPORTANCE Current guidelines allow substantial discretion in use of noninvasive cardiac imaging for patients without acute myocardial infarction (AMI) who are being evaluated for ischemia. Imaging use may affect downstream testing and outcomes.

OBJECTIVE To characterize hospital variation in use of noninvasive cardiac imaging and the association of imaging use with downstream testing, interventions, and outcomes.

DESIGN, SETTING, AND PARTICIPANTS Cross-sectional study of hospitals using 2010 administrative data from Premier, Inc, including patients with suspected ischemia on initial evaluation who were seen in the emergency department, observation unit, or inpatient ward; received at least 1 cardiac biomarker test on day 0 or 1; and had a principal discharge diagnosis for a common cause of chest discomfort, a sign or symptom of cardiac ischemia, and/or a comorbidity associated with coronary disease. We excluded patients with AMI.

MAIN OUTCOMES AND MEASURES At each hospital, the proportion of patients who received noninvasive imaging to identify cardiac ischemia and the subsequent rates of admission, coronary angiography, and revascularization procedures.

RESULTS We identified 549,078 patients at 224 hospitals. The median (interquartile range) hospital noninvasive imaging rate was 19.8% (10.9%-27.7%); range, 0.2% to 55.7%. Median hospital imaging rates by quartile were Q1, 6.0%; Q2, 15.9%; Q3, 23.5%; Q4, 34.8%. Compared with Q1, Q4 hospitals had higher rates of admission (Q1, 32.1% vs Q4, 40.0%), downstream coronary angiogram (Q1, 1.2% vs Q4, 4.9%), and revascularization procedures (Q1, 0.5% vs Q4, 1.9%). Hospitals in Q4 had a lower yield of revascularization for noninvasive imaging (Q1, 7.6% vs Q4, 5.4%) and for angiograms (Q1, 41.2% vs Q4, 38.8%). P < .001 for all comparisons. Readmission rates to the same hospital for AMI within 2 months were not different by quartiles (P = .51). Approximately 23% of variation in imaging use was attributable to the behavior of individual hospitals.

CONCLUSIONS AND RELEVANCE Hospitals vary in their use of noninvasive cardiac imaging in patients with suspected ischemia who do not have AMI. Hospitals with higher imaging rates did not have substantially different rates of therapeutic interventions or lower readmission rates for AMI but were more likely to admit patients and perform angiography.

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chest pain is the second most common cause of emergency
department visits in the United States and ac-
counts for billions of dollars in annual hospital costs.1,2
Most patients who present with chest pain do not have acute
myocardial infarction (AMI).3 During the initial evaluation of
chest pain, clinicians have many options, including the use of
stress testing with noninvasive cardiac imaging, to deter-
mine patients’ risk for a cardiovascular event. Unfortunately,
clinical guidelines often do not provide strong recommenda-
tions about which testing strategies should be applied to which
patients among the clinically heterogeneous group that pre-
sents with suspected ischemia.4,5
To our knowledge, there are no published studies that com-
pare hospitals’ approaches to the evaluation of patients pre-
senting with possible ischemic heart disease who do not have
AMI. In particular, physicians face a decision about the use of
noninvasive imaging in stress testing. Imaging studies result in
substantial health care costs and often possible radiation
exposure.6 To justify their use, imaging tests should there-
fore lead to better decisions and better patient outcomes.7 Hos-
pitals have developed different diagnostic approaches, includ-
ing the creation of units dedicated to assessing suspected
myocardial ischemia with either mandatory or optional non-
invasive cardiac imaging.7–11
The implications of variation may be far-reaching. Patient-
level studies have shown that frequent use of noninvasive car-
diac imaging is associated with a greater likelihood of inva-
sive and expensive downstream tests, such as catheterization
for coronary angiography.12,13 Evidence of marked hospital-
level variation in cardiac imaging practices would highlight a
need to clarify the marginal benefit of more expensive strat-
egies for patients with suspected ischemia.
We sought to determine whether hospital use of nonin-
vasive cardiac imaging was associated with patterns of down-
stream resource use, including inpatient hospitalization and
catheterization for coronary angiography. Furthermore, we
sought to determine whether hospitals that frequently used
noninvasive cardiac imaging subsequently performed revas-
cularization procedures at a substantially different rate. We also
sought to determine whether hospitals that more frequently
used noninvasive imaging had a different yield of revascular-
zation for both noninvasive imaging testing and angio-
grams. Finally, we investigated whether more frequent use of
cardiac imaging among hospitals was ultimately associated with fewer readmissions for AMI to the same hospital.

Methods

Data Source
We conducted a cross-sectional study of acute care hospitals
in the United States using a database maintained by Premier,
Inc. The Premier database includes administrative, opera-
tional, and some clinical data from 2700 hospitals in the United
States.14 Of the 2700 hospitals that submitted data, 372 hos-
pitals signed an agreement to have their data used for the pur-
poses of academic research and were eligible for inclusion in
our study. The database contains a date-stamped log of all billed
items at the individual patient level including medications and
laboratory, diagnostic, and therapeutic services. For this study,
Premier deidentified patient data in accordance with the Health
Insurance Portability and Accountability Act, and random,
unique patient and hospital identifiers were applied to each
record to facilitate analysis. The Yale University Human In-
vestigation Committee exempted this study protocol from re-
view by the Office of Human Research Protections.

Study Cohort
We included hospital visits that occurred in 2010, including
those restricted to the emergency department, those in which
the patient stayed in a bed coded as observation status, and
those in which a patient was admitted to an inpatient bed. In
order to include patients in whom cardiac ischemia was being
considered as a primary diagnosis, we required patients to have
received at least 1 cardiac biomarker test to assess for myocar-
dial ischemia, defined as either a serum cardiac troponin or cre-
atine kinase MB test on day 0 (day of the initial encounter) or
day 1 of the hospital visit.
In addition, patients were included if the principal dis-
charge diagnosis was among a selected group of Interna-
tional Classification of Diseases, Ninth Revision, Clinical Mod-
ification (ICD-9-CM) discharge diagnoses (eTable 1 in
Supplement). These codes were selected on the basis of a re-
view by 3 of us (K.C.S., K.D., A.K.V.) to determine whether they
met any of the following criteria: (1) a common cause of chest
discomfort; (2) a symptom or sign that can be associated with
cardiac ischemia; or (3) a diagnosis that is often comorbid
with coronary artery disease. Patients with a principal discharge
diagnosis of AMI were excluded.
We excluded patients with principal discharge diagnoses
for acute illnesses, which may warrant cardiac biomarker test-
ing but not additional ischemic evaluation, including aortic
dissection and pulmonary embolism (eTable 2 in Supplement).
We excluded visits if patients were younger than 35 years, trans-
ferred in from another hospital, or transferred out to another
hospital. We also excluded patient visits in which cardiac bio-
markers may have been ordered for preoperative or periopera-
tive evaluation (eTable 3 in Supplement). We excluded hospi-
tals that performed fewer than 5 revascularization procedures
during the study period.

Outcomes
The primary outcome for each hospital was the proportion of
eligible patients who received noninvasive cardiac imaging test-
ing for ischemia. These tests included stress nuclear myocardial
fusion imaging, stress echocardiography, cardiac positron
emission tomography, cardiac magnetic resonance imaging, and
cardiac computed tomography with coronary angiography (CTCA)
with or without calcium scoring.
To determine the association of noninvasive imaging use
with downstream resource use, we calculated subsequent hos-
pital-level proportions of inpatient hospitalization, coronary
angiography, and revascularization (either percutaneous coro-
nary intervention or coronary artery bypass graft surgery).
We considered cardiac imaging tests, catheterizations for
coronary angiography, and revascularization procedures as out-
comes if they occurred within the same month or in the month following the index hospital visit. Finally, we calculated readmissions for AMI as the proportion of patients who returned to the same hospital with a principal discharge diagnosis of AMI (ICD-9-CM codes 410.x, excluding 410.x2) within the same month or in the month following the index hospital visit.

Statistical Analyses
We divided hospitals into quartiles based on the proportion of patients who received noninvasive imaging tests for cardiac ischemia. We compared quartiles of hospitals using χ² tests. We compared the proportion of patients receiving specific imaging modalities across quartiles. We determined the association of noninvasive imaging with downstream resource utilization across quartiles by calculating the number of patients in each quartile who were admitted to an inpatient bed during their index hospital encounter, received catheterization for a coronary angiogram after undergoing noninvasive imaging, and received a revascularization procedure. We determined the association of imaging with outcomes by using χ² tests to compare, across quartiles, the proportion of patients who were readmitted with AMI to the same hospital as that of their index encounter during the same month or the month following the index hospital visit. For all analyses, we considered P < .05 to be statistically significant.

We also fit 3 hierarchical logistic regression models to investigate the degree to which patient case mix and hospital structural factors accounted for the variation in use of noninvasive imaging. We first fit an unconditional model with only a hospital random intercept to determine whether any hospital-level variation existed. In the second model, we added patient characteristics, including age and sex, to investigate the extent to which differences in cardiac imaging use across hospitals were accounted for by patient case mix. In the third model, we added hospital characteristics to determine whether the variation among hospitals could be accounted for by known hospital characteristics such as region, teaching status, or bed size. For each of the models, we calculated the between-hospital variance and reported the interclass correlation coefficient (ICC) to measure the proportion of variance that was attributable to the between-hospital variation and the median odds ratio to quantify the between-hospital variation in the use of imaging.

Results
Cardiac Imaging Rates and Hospital Characteristics
We included 549 078 patients treated at 224 hospitals in the United States (eFigure 1 in Supplement). The median (interquartile range [IQR]) number of hospital beds was 360 (250-462). Hospitals tended to be located in the South (41%), serve an urban population (88%), and identify as nonteaching (66%).

The noninvasive cardiac imaging rates for hospitals ranged from 0.2% to 55.7% (median [IQR], 19.8% [10.9%-27.7%]) (Figure 1). When hospitals were divided into quartiles based on imaging rates, median rates of imaging were Q1, 6.0%; Q2, 15.9%; Q3, 23.5%; Q4, 34.8%.

Hospitals in higher quartiles of noninvasive imaging use had similar characteristics in terms of bed size (P = .13), availability of observation beds (P = .87), urban or rural location (P = .93), and teaching status (P = .44) (Table 1). Hospitals in higher imaging quartiles were more likely to be located in the Midwest and Northeast (P < .001) (Table 1).

Myocardial perfusion imaging and stress echocardiography were the most commonly used imaging modalities (Figure 2). A total of 113 602 imaging tests were performed in our study cohort. Of these, 80.4% were myocardial perfusion images (91 336), 16.6% were echocardiograms (18 858), and 1.2% were CTCAs (1365). There were no statistically significant differences between hospitals in different imaging quartiles in terms of the rates at which they used specific modalities when performing noninvasive cardiac imaging (Table 2).

Downstream Admissions, Testing, and Procedures
Hospitals in higher imaging use quartiles admitted a larger proportion of patients to an inpatient bed (Q1, 32.1% vs Q4, 40.0%; P < .001) (Table 3).
Table 1. Hospital Characteristics Compared by Hospital Imaging Quartiles

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Q1 (n = 56)</th>
<th>Q2 (n = 56)</th>
<th>Q3 (n = 56)</th>
<th>Q4 (n = 56)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of beds</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-200</td>
<td>12</td>
<td>18</td>
<td>14</td>
<td>14</td>
<td>.13</td>
</tr>
<tr>
<td>201-400</td>
<td>62</td>
<td>45</td>
<td>34</td>
<td>43</td>
<td></td>
</tr>
<tr>
<td>401-600</td>
<td>14</td>
<td>30</td>
<td>32</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>&gt;600</td>
<td>11</td>
<td>7</td>
<td>20</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>Have observation stay patients</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>80</td>
<td>77</td>
<td>77</td>
<td>82</td>
<td>.87</td>
</tr>
<tr>
<td>No</td>
<td>20</td>
<td>23</td>
<td>23</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>Geographic region</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Midwest</td>
<td>4</td>
<td>21</td>
<td>32</td>
<td>36</td>
<td></td>
</tr>
<tr>
<td>Northeast</td>
<td>9</td>
<td>16</td>
<td>14</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>South</td>
<td>46</td>
<td>39</td>
<td>41</td>
<td>38</td>
<td></td>
</tr>
<tr>
<td>West</td>
<td>41</td>
<td>23</td>
<td>12</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>Population served</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>.93</td>
</tr>
<tr>
<td>Urban</td>
<td>88</td>
<td>89</td>
<td>89</td>
<td>86</td>
<td></td>
</tr>
<tr>
<td>Rural</td>
<td>12</td>
<td>11</td>
<td>11</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>Teaching status</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>.44</td>
</tr>
<tr>
<td>Nonteaching</td>
<td>73</td>
<td>68</td>
<td>59</td>
<td>64</td>
<td></td>
</tr>
<tr>
<td>Teaching</td>
<td>27</td>
<td>32</td>
<td>41</td>
<td>36</td>
<td></td>
</tr>
</tbody>
</table>

Abbreviation: Q, quartile.

*Hospitals were divided into quartiles based on the proportion of patients who received noninvasive imaging tests for cardiac ischemia, from Q1 with the lowest proportion to Q4 with the highest.

Figure 2. Proportion of Cardiac Imaging Tests of Different Modality Types

Each bar represents 1 hospital. CT indicates computed tomography; MRI, magnetic resonance imaging; PET, positron emission tomography.
Hospital angiogram rates ranged from 0% to 16.9% (median [IQR], 2.5% [1.4%-4.1%]). There was only 1 hospital with an angiogram rate greater than 10%. Hospitals in higher imaging use quartiles more frequently performed downstream coronary angiography (Q1, 1.2% vs Q4, 4.9%; \( P < .001 \)) (Table 3).

The rate of revascularization procedures ranged from 0% to 9.5% (median [IQR], 0.8% [0.4%-1.4%]). Hospitals in higher imaging use quartiles performed slightly more revascularization procedures compared with those in lower imaging quartiles (Q1, 0.5% vs Q4, 1.9%; \( P < .001 \)) (Table 3). Hospitals in the top imaging quartile had a lower revascularization yield per imaging study compared with hospitals in the lowest quartile (Q1, 7.6% vs Q4, 5.4%; \( P < .001 \)) (Table 3). Similarly, the yield in revascularizations per angiogram was also lower at hospitals in the highest imaging quartile compared with hospitals in the lowest quartile (Q1, 41.2% vs Q4, 38.8%; \( P < .001 \)) (Table 3).

Outcomes
All quartiles had a similar proportion of patients readmitted for AMI within the same or the subsequent month (0.3% for all quartiles; \( P = .51 \)) (Table 3).

Institutional Effects and Cardiac Imaging Use
The ICCs (95% CI) for the unconditional (unadjusted) model, the model adjusted for patient age and sex, and the model further adjusted for hospital characteristics were 23.2 (19.5-26.5), 23.3 (19.6-26.6), and 16.1 (8.6-22.4), respectively (Table 4), indicating that approximately 23% of the variation in rates of noninvasive cardiac imaging was attributable to between-hospital variation and that this variation was not significantly affected by hospital patient mix. The median odds ratio was 2.6 for the unconditional model and for the age and sex-adjusted model and 2.1 for the model with hospital characteristics, indicating that a randomly selected patient receiving noninvasive cardiac imaging at a particular hospital would have approximately 2-fold

### Table 2. Types of Imaging Modalities Used by Hospitals Compared by Hospital Imaging Quartiles

<table>
<thead>
<tr>
<th>Imaging Type</th>
<th>Proportion, Median (Range), %</th>
<th>Total (N = 224)</th>
<th>Proportion, Median, %</th>
<th>Q1 (n = 56)</th>
<th>Q2 (n = 56)</th>
<th>Q3 (n = 56)</th>
<th>Q4 (n = 56)</th>
<th>P Valueb</th>
</tr>
</thead>
<tbody>
<tr>
<td>Myocardial perfusion imaging nuclear medicine</td>
<td>92.9 (0.6-100)</td>
<td>92</td>
<td>96</td>
<td>94</td>
<td>91</td>
<td>.47</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Echocardiogram</td>
<td>3.6 (0-98.7)</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>6</td>
<td>.21</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coronary CT angiogram with or without calcium score</td>
<td>0 (0-29.1)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>.46</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cardiac MRI</td>
<td>0 (0-17.0)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>.61</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PET scan</td>
<td>0 (0-14.6)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>.56</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt;1 type</td>
<td>0.2 (0-48.9)</td>
<td>0</td>
<td>0.2</td>
<td>0.4</td>
<td>0.7</td>
<td>&lt;.001</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Abbreviations: CT, computed tomographic; MRI, magnetic resonance imaging; Q, quartile; PET, positron emission tomography.

a Hospitals were divided into quartiles based on the proportion of patients who received noninvasive imaging tests for cardiac ischemia, from Q1 with the lowest proportion to Q4 with the highest.

b Kruskal-Wallis test.

### Table 3. Utilization and Patient Outcomes Compared by Hospital Imaging Quartiles

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Q1 (n = 129 021)</th>
<th>Q2 (n = 123 648)</th>
<th>Q3 (n = 149 668)</th>
<th>Q4 (n = 146 741)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Imaging, %</td>
<td>6.0</td>
<td>15.9</td>
<td>23.5</td>
<td>34.8</td>
<td>...</td>
</tr>
<tr>
<td>Inpatient admission, %</td>
<td>32.1</td>
<td>37.0</td>
<td>37.8</td>
<td>40.0</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Received coronary angiogram, %</td>
<td>1.2</td>
<td>2.2</td>
<td>3.3</td>
<td>4.9</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Received revascularization, %</td>
<td>0.5</td>
<td>0.9</td>
<td>1.2</td>
<td>1.9</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Revascularizations per imaging study, No.</td>
<td>7.6</td>
<td>5.6</td>
<td>4.9</td>
<td>5.4</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Revascularizations per angiogram, No.</td>
<td>41.2</td>
<td>40.9</td>
<td>36.4</td>
<td>38.8</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Readmission with AMI, %</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
<td>.51</td>
</tr>
</tbody>
</table>

Abbreviations: AMI, acute myocardial infarction; Q, quartile.

* Hospitals were divided into quartiles based on the proportion of patients who received noninvasive imaging tests for cardiac ischemia, from Q1 with the lowest proportion to Q4 with the highest.

### Table 4. Hospital Effects on Use of Imaging

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Empty Model</th>
<th>Age and Sex</th>
<th>Age, Sex, and Hospital Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>C statistic (95% CI)</td>
<td>0.7 (0.7-0.7)</td>
<td>0.7 (0.7-0.7)</td>
<td>0.7 (0.7-0.7)</td>
</tr>
<tr>
<td>Random-effects hospital-level variance, ( \sigma^2 ) (95% CI)</td>
<td>1.0 (0.8-1.2)</td>
<td>1.0 (0.8-1.2)</td>
<td>0.6 (0.3-1.0)</td>
</tr>
<tr>
<td>ICC, % (95% CI)a</td>
<td>23.2 (19.5-26.5)</td>
<td>23.3 (19.6-26.6)</td>
<td>16.1 (8.6-22.4)</td>
</tr>
<tr>
<td>Odds ratio, medianb</td>
<td>2.6</td>
<td>2.6</td>
<td>2.1</td>
</tr>
</tbody>
</table>

Abbreviation: ICC, interclass correlation.

a ICC is calculated as \( \sigma^2/[\sigma^2+(\pi^2/3)] \).

b Median odds ratio is calculated as exp(0.95\( \sigma \)).
Discussion

Our study indicates substantial hospital-level variation in the use of noninvasive imaging for cardiac ischemia in patients without AMI who are undergoing further evaluation for coronary artery disease. Higher rates of imaging use at the hospital level were associated with greater use of downstream coronary angiography. However, we observed that hospitals that more frequently engaged in testing did not have substantially higher rates of revascularization; hospitals in the highest imaging use quartile had the lowest yields with regard to revascularization. Furthermore, high imaging use hospitals did not achieve lower rates of same-hospital readmission with AMI. These findings suggest that more frequent use of noninvasive cardiac imaging at a large, diverse group of hospitals in the United States was associated with greater rates of patient admission and use of invasive downstream diagnostic tests without evidence of a substantial effect on the use of therapeutic interventions or short-term outcomes.

We could not directly determine whether imaging was appropriate for an individual patient. Our aim was to characterize hospital-level patterns of imaging use rather than to determine the appropriateness of individual provider decisions, and it is unlikely that patient case mix would account for the wide variation in imaging rates among hospitals that we observed. Furthermore, high imaging use hospitals had a lower yield to angiogram and coronary revascularization and had the same readmission outcomes compared with low imaging use hospitals, suggesting the need to clarify the benefit to patients of higher rates of imaging use.

Our results extend the literature that demonstrates variation in the use of diagnostic modalities in the evaluation of common acute clinical presentations. Studies have shown particularly high variation in clinical scenarios in which guidelines are not well established, including neuroimaging in the evaluation of dizziness, headache, trauma, and epilepsy. For subgroups of patients in which guidelines are well established, such as pediatric neuroimaging, variation is considerably less. In comparison, clinical guidelines do not clearly identify which patients among the heterogeneous group presenting with suspected myocardial ischemia should receive cardiac imaging.

Moreover, our findings are similar to those of studies examining the relationship between increased use of a diagnostic modality and patient outcomes. For example, despite the increasing rates of imaging with computed tomography for stroke and pulmonary embolism, rates of diagnosis have not changed. One potential explanation for unchanged outcomes despite higher rates of cardiac imaging is that hospitals that use imaging more frequently are doing so in patients for whom the benefit is not clear. Again, without a strong evidence base to inform guideline development, the choice of which patients are likely to benefit from imaging may not be readily apparent.

Despite uncertainty in the value of testing, single-center studies have demonstrated that patients frequently receive noninvasive cardiac imaging for ischemia, regardless of pretest probability of coronary artery disease. However, when imaging is used in a broader patient population, false-positive results will increase. These results can increase referral for angiograms that subsequently reveal clinically insignificant lesions. Our findings are consistent with this relationship because hospitals that performed noninvasive imaging in the highest proportion of their patients had higher rates of angiography but the lowest yields in subsequent revascularization. These findings indicate the need to clarify which patients being evaluated for cardiac ischemia would most benefit from additional imaging studies.

The yield of revascularization for noninvasive imaging and for angiography was derived by grouping all patients from hospitals within the same imaging quartile together and calculating the mean yield. Thus, we believe that the yield associated with each quartile was not sensitive to an individual hospital’s or provider’s tendency to perform angiography or revascularization. The goal of our study was not to characterize the practice of an individual hospital or provider as being more or less aggressive or higher or lower in quality.

In an attempt to understand the factors that may be responsible for variation in imaging practices, we conducted a hierarchical logistical regression analysis. We found that between-hospital differences in patient case mix did not account for the majority of the variation. Rather, our study demonstrates that the likelihood of a given testing strategy being used for an individual patient depends largely on the particular hospital at which the patient receives care. However, additional work is necessary to understand the organizational, cultural, and financial aspects of hospital practice that may influence imaging decisions. Previous literature suggests that many hospitals may use specific protocols to evaluate patients with suspected ischemia, including the standard use of cardiac imaging to rule out coronary disease. Other studies have demonstrated increases in utilization and spending in physician practices that have purchased expensive imaging equipment. It is plausible that hospitals may experience similar financial motivations.

Although we included a diverse cohort of hospitals in this study, there may be some questions about the generalizability of our sample. Our cohort of patients was highly specific for individuals who are evaluated for cardiac ischemia. Because the Premier database indicates whether a patient received a cardiac troponin test, we avoided the selection bias and misclassification of patients that could result from solely relying on principal discharge diagnoses to identify those with suspected ischemia. We included a non–chest pain code if the code represented a common cause of chest pain, a symptom commonly associated with chest pain, and/or a comorbidity that may cause concern for obstructive coronary disease. Thus, we believe that our cohort represents the full spectrum of patients in whom cardiac ischemia may be considered as a primary diagnosis.

Our study has several limitations. We were not able to track whether a hospital referred a patient for cardiac imaging to a different hospital or private physician office. However, it is unlikely that hospitals with the capability to perform cardiac imaging (all of the hospitals in our study) would refer patients to another hospital for an imaging study. Moreover, patients may...
seek care at multiple hospitals, and we were not able to capture downstream testing and revascularization if it occurred at a hospital different from that of the index encounter. In addition, although our hospital cohort included more than 220 institutions with diverse characteristics, all voluntarily participate in a consortium that gathers and shares data with the aim of improving practice. We could also only capture readmissions for AMI if the patient was readmitted to the same hospital at which he or she was initially evaluated. Although this may mean that readmission rates were in fact higher than what we report, it is unlikely that the relative readmission rates between hospitals would differ. Furthermore, it is possible that the threshold that individual health care providers use to decide whether to order tests of cardiac biomarkers may have indirectly affected the rate of cardiac imaging use by altering the types of patients included in the cohort at each hospital. We believe that this possibility is unlikely given that the relative mix of discharge diagnoses was similar across the hospital quartiles (eTable 4 in Supplement).

Conclusions

In a health care system that faces increasing resource constraints, it is critical to identify opportunities to reduce resource use that is not associated with improved patient outcomes. We observed substantial variation in the use of cardiac imaging in patients who present for evaluation of ischemia but much smaller differences in the rates of revascularization and no difference in readmission outcomes. An important determinant of whether these expensive tests were used was the hospital at which the patient received care.

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Author Contributions: Dr Li had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

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The etiology of chest pain is serious in only a distinct minority of the multitude of patients who visit the emergency department (ED) with this symptom each year, but the consequences of missing acute coronary syndrome or other life-threatening conditions can include grave clinical sequelae and major liability. Thus, the dilemma of low risk but high stakes in this patient population continues to spur efforts to optimally serve both groups by rapid identification of those requiring urgent treatment and safe, cost-effective, and early discharge in the large majority with a benign condition. The contemporary approach to this challenge in many centers has evolved into accelerated diagnostic protocols (ADPs) that entail initial recognition of low risk based on clinical stability, normal electrocardiogram, and negative results for cardiac injury markers followed by a predischarge test to evaluate suitability for early discharge.1 Predischarge tests vary from exercise treadmill to stress imaging or computed tomographic coronary angiography (CTA), depending on institutional resources, expertise, and physician preference. Negative results allow discharge with outpatient follow-up while abnormal findings mandate admission. During more than 2 decades, this strategy has averted unnecessary admissions, reduced length of stay (LOS), and resulted in safe clinical outcomes.1 Indeed, ADPs have been associated with a greater than 99% negative predictive value for adverse cardiac events at 30 days or longer2 and have reduced the classic “rule out myocardial infarction [MI]” process from days to hours. However, despite these estimable results, the logic of routine cardiac testing for these low-risk patients has recently been sharply challenged on the grounds of clinical rationale,2 resource utilization, and cost—ironically, the same bases on which the case for cardiac testing was formulated.

The report by Safavi et al3 in this issue of JAMA Internal Medicine is germane to this question. In their study of hospital use of noninvasive cardiac imaging (NICI) methods in a very large patient population evaluated for chest pain suspicious for myocardial ischemia, they found that (1) hospital use of NICI in these patients varied widely, (2) hospitals with higher NICI rates more frequently admitted patients for angiography, but (3) increased NICI rates were not associated with substantial differences in revascularization rates or readmission for MI. It might be concluded from these findings that the NICI did not provide any clinical advantage in the management of these patients and that the authors identified high utilization of an expensive resource that was not associated with substantial clinical gain. However, potential benefits resulting from the evaluation sequence but not assessed in this study could have included improved medical therapy for patients with cardiac disease who did not require revascularization and also reduced ED visits for chest pain in those shown to have no clinically significant disease. Thus, further study of outcomes in this population would be useful.

The results of the study by Safavi et al3 offer a strikingly different perspective than that presented earlier in this commentary on the utility of cardiac testing, including NICI, in achieving salutary outcomes of ADPs in patients presenting with chest pain without MI. Their study is one of an increasing number of reports asserting that routine cardiac testing of low-risk patients presenting to the ED with chest pain is neither necessary nor cost-effective. Prasad et al4 cogently reviewed the evidence against routine testing of low-risk patients presenting with chest pain in terms of absence of improved clinical outcomes, increased costs, and obsolete rationale. Furthermore, the utility of excluding MI with a recently developed 2-hour diagnostic protocol using high-sensitivity troponin in patients with a normal result from an electrocardiogram and a thrombolysis in myocardial infarc-

### References


### Invited Commentary

**The Patient With Chest Pain**

**Low Risk, High Stakes**

Ezra A. Amsterdam, MD; Edris Aman, MD

The etiology of chest pain is serious in only a distinct minority of the multitude of patients who visit the emergency department (ED) with this symptom each year, but the consequences of missing acute coronary syndrome or other life-threatening conditions can include grave clinical sequelae and major liability. Thus, the dilemma of low risk but high stakes in this patient population continues to spur efforts to optimally serve both groups by rapid identification of those requiring urgent treatment and safe, cost-effective, and early discharge in the large majority with a benign condition. The contemporary approach to this challenge in many centers has evolved into accelerated diagnostic protocols (ADPs) that entail initial recognition of low risk based on clinical stability, normal electrocardiogram, and negative results for cardiac injury markers followed by a predischarge test to evaluate suitability for early discharge.1 Predischarge tests vary from exercise treadmill to stress imaging or computed tomographic coronary angiography (CTA), depending on institutional resources, expertise, and physician preference. Negative results allow discharge with outpatient follow-up while abnormal findings mandate admission. During more than 2 decades, this strategy has averted unnecessary admissions, reduced length of stay (LOS), and resulted in safe clinical outcomes.1 Indeed, ADPs have been associated with a greater than 99% negative predictive value for adverse cardiac events at 30 days or longer2 and have reduced the classic “rule out myocardial infarction [MI]” process from days to hours. However, despite these estimable results, the logic of routine cardiac testing for these low-risk patients has recently been sharply challenged on the grounds of clinical rationale,2 resource utilization, and cost—ironically, the same bases on which the case for cardiac testing was formulated.

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